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Vacuum Brazing Process for Large-Scale Grid Production for Negative Ion Source Application

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Large grids used in ion beam generation from an ion source are exposed to high heat flux and therefore require active cooling. To address this, cooling channels are embedded within the grids. Traditionally, these embedded channels have been fabricated through electroforming, as implemented in systems like JET-PINI, BATMAN and ITER-DNB. Recently, efforts have been made to manufacture a full-scale grid set for TWIN source—a two-driver, RF-based negative ion source using vacuum brazing as an alternative technique. Due to its ability to produce millimeter-scale embedded cooling channels, the vacuum brazing method has demonstrated potential applications for other plasma-facing components as well.

Vacuum brazing offers several advantages over conventional copper electroforming. It is more economical and environmentally friendly, provides better repeatability, induces lower residual stresses, allows for improved distortion control, and is generally less time-consuming. Due to restricted information, the electroforming technique in a few countries or companies maintains a monopoly. Vacuum brazing can be considered as an alternative technique for manufacturing large-size grid segments more economically.

The cooling geometry of the grids has been optimized through a combination of finite element analysis (FEA), prototype fabrication, and experimental validation. A critical aspect of this development is the characterization of the brazed joint, which must withstand operational water pressures at temperatures ranging from 100℃ to 150℃. Fixtures are selected to maintain a precise gap clearance of 50–100 microns throughout the brazing cycle. Post-brazing, the grid segments achieve a flatness within the range of 200–400 microns. The process also incorporates various inspections and testing methods, including cold and hot helium leak testing, infrared thermography, and radiographic testing (RT), ensuring the integrity and performance of the final grid segments.

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